CONCRETE PILES

AT THE

United States Naval Academy

ANNAPOLIS, MD.

By

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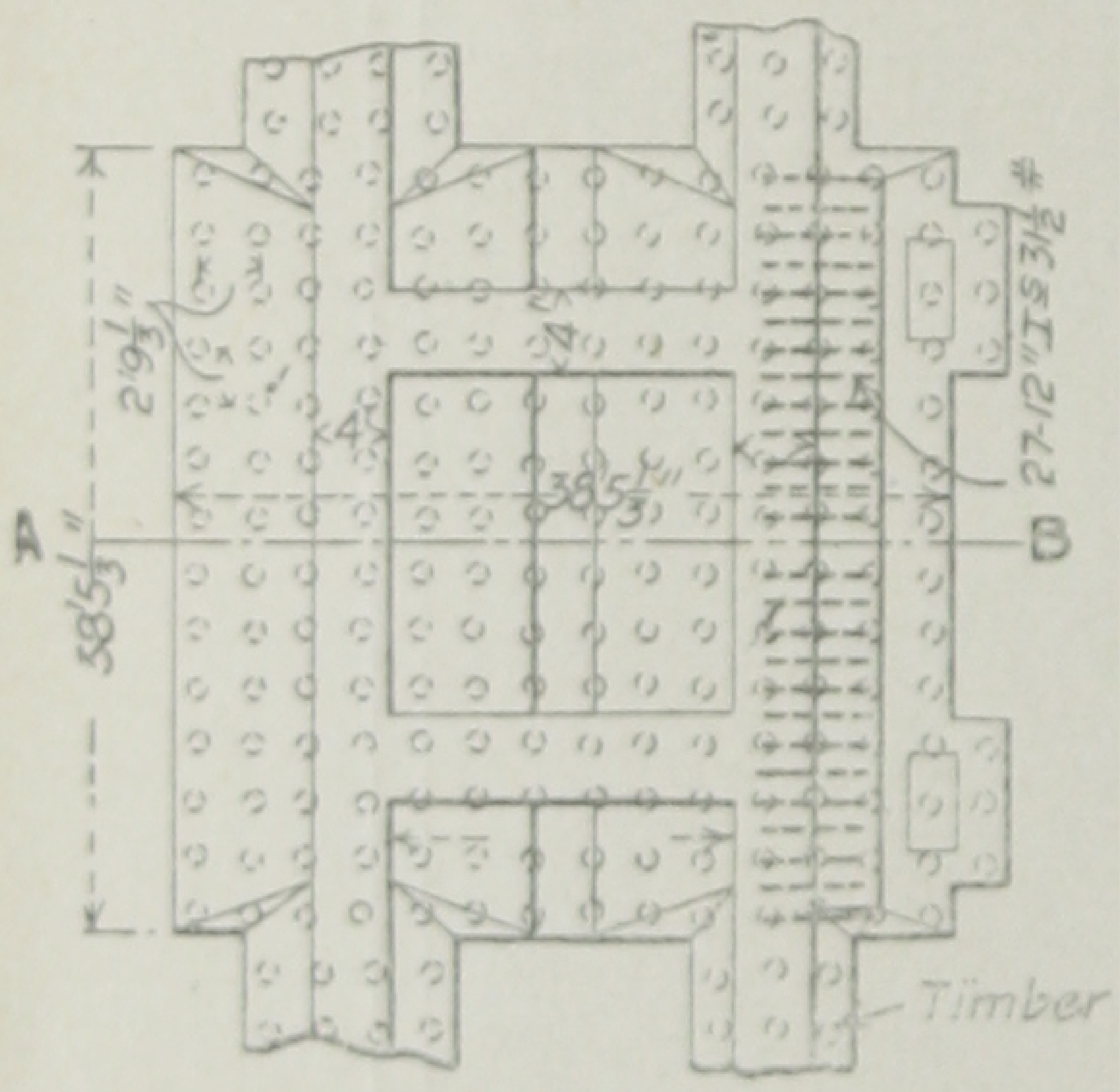
After the value of an efficient navy was made evident by the war with Spain, Congress made appropriations, from time to time, amounting to $10,000,000 to rebuild the Naval Academy at Annapolis, Md. The plans of Mr. Ernest Flagg, architect, of New York, were selected for the new academy. These plans contemplated a new sea wall, armory, seamanship building, midshipmen's quarters, gymnasium, hospital, chapel, officers' quarters, officers' mess building, steam engineering building, power house and academic group.

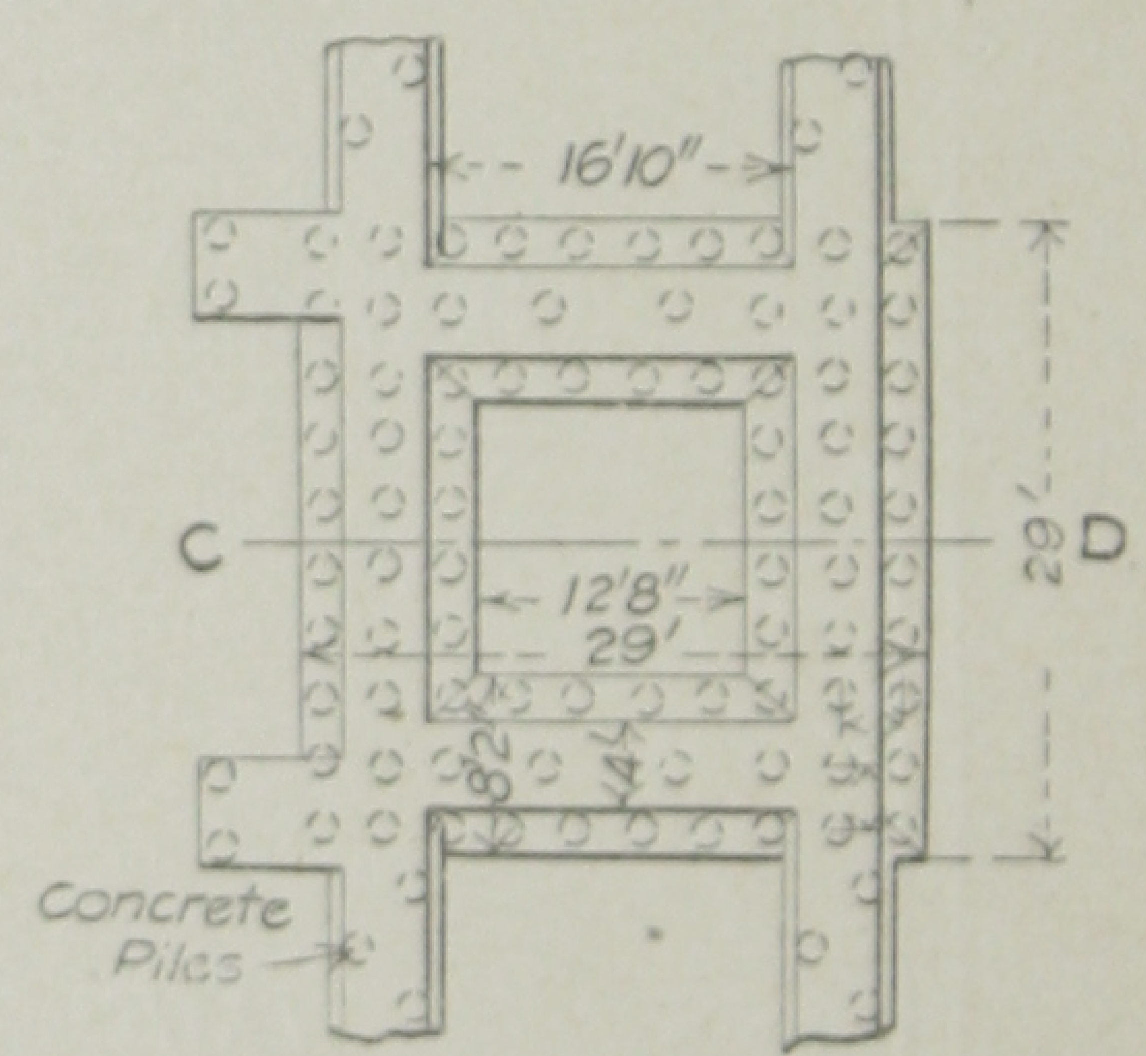


Plan

The academic group, the foundations of which are the subject of this article, consists of the library building, of granite and brick, about 150x133 ft., three stories high, with a central tower about 140 ft. in height containing a revolving dome for astronomical work. On one side of the library is a wing known as the physics and chemistry building and on the other the academic building. These two wings are also of granite and brick and nearly of the same design, three stories in height and about 229x84 ft. each. This group, taken as a whole, is one of the largest buildings in the country devoted to educational purposes.

The soil on the site of the physics and chemistry building was of such a nature that piles were not required, but they were necessary under both the library and academic buildings, a portion of this land having been reclaimed from the Severn River by filling with sand and mud by means of dredges, three years previous to the beginning of these foundations.

Certain amounts of the appropriation were allotted to the various buildings. When the bids for the academic group were opened, the lowest that of John Pierce, of New York, was found to far exceed the $1,500,000 allotted for the group, and some method had to be resorted to which would reduce the cost and still preserve the



Plan

general plans of the buildings. Concrete piles were suggested, and upon investigation it was found that by their substitution for the wood piles shown in the original plans, the cost would be reduced about $27,000. Owing to the fact that wood will decay rapidly if not permanently covered with water, it is necssary to cut wood

piles off at mean low water, and the concrete footings must start from this point and be carried up to the height of the bottom of the walls. With concrete piles, the tops are left just far enough below the bottom of the walls to allow for a concrete beam thick enough to carry the weight of the building.

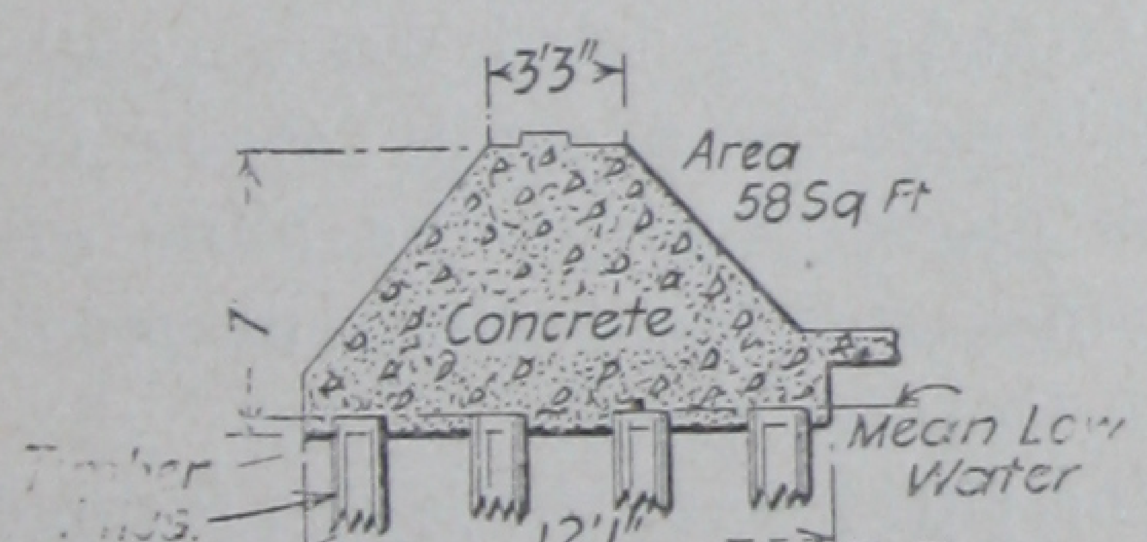
This difference in thickness of concrete footings is well illustrated by a section of the footings of the academic building with wood piles and the same section as redesigned and built with concrete piles. This saving in excavation and footings depends upon the height of the building above mean low water. At the Naval Academy the rise and fall of the tide in the Severn River is very slight, consequently the buildings have been placed only a few feet above mean low water. Notwithstanding that the cost per lineal foot for concrete piles far exceeds that of wood piles, being about four times as much, the saving in the entire foundation by their use will surprise the uninitiated, as will be seen by a glance at the cuts shown here.

In the accompanying diagrams the section E-F shows the footing of the connection between the library and academic buildings as designed by Mr. Flagg for wood piles. Another sketch shows the same section, G-H in the diagram as built with concrete piles. The depth of footing on this section was reduced from 7 ft. to 2 ft. 8 in., and the width on the bottom from 12 ft. 1 in. to 5 ft. 2 in. The area of the cross section was reduced from 58 to 12 sq. ft. In the plan of the wood piles under the library tower there are 202 piles in a rectangle 38 ft. 5⅓ in. square. The plan of the same tower foundation with 84 concrete piles has footings 8 ft. 2 in. wide.

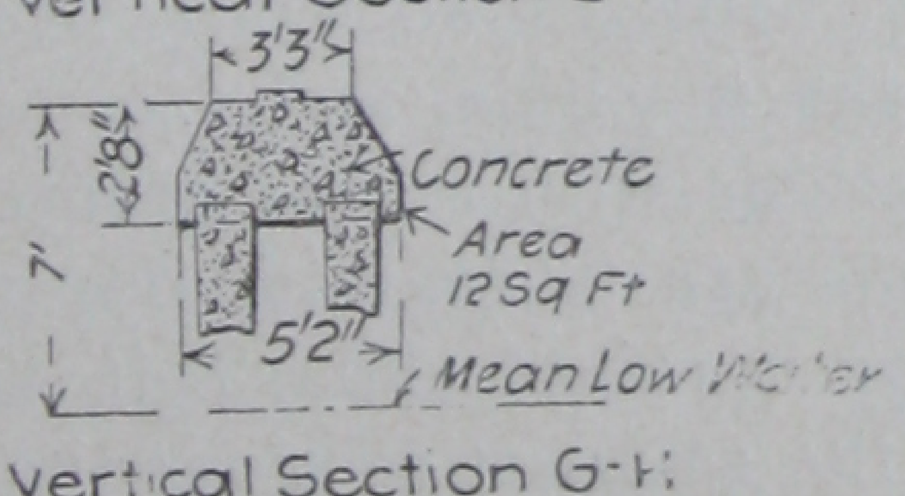
With wood piles it will be noticed that the piles and footings extend over the entire rectangle, while with concrete piles the piles and footings are only 8 ft. 2 in. wide and directly under the walls of the tower. The depth of the footing was reduced by the use of concrete piles from 10 ft. 1½ in. to 4 ft. 7⅓ in. Twenty-seven 12-in. 31½-lb. I-beams were done away with.

The following reductions on the foundations of the two buildings were made by the use of concrete piles; 2,193 wood piles were replaced by 885 concrete piles; 4,542 yd. of excavation were reduced to 1,038 yd., saving 3,504 yd., and 3,250 yd. of concrete footings were reduced to 986 yd., saving 2,264 yd.

With wood piles, after excavating to mean low water, shoring and pumping would have been necessary in all trenches, and this saving was estimated at $4,000. A schedule of changes showing the saving by the use of concrete piles is given in Table 1.



Vertical Section E-F



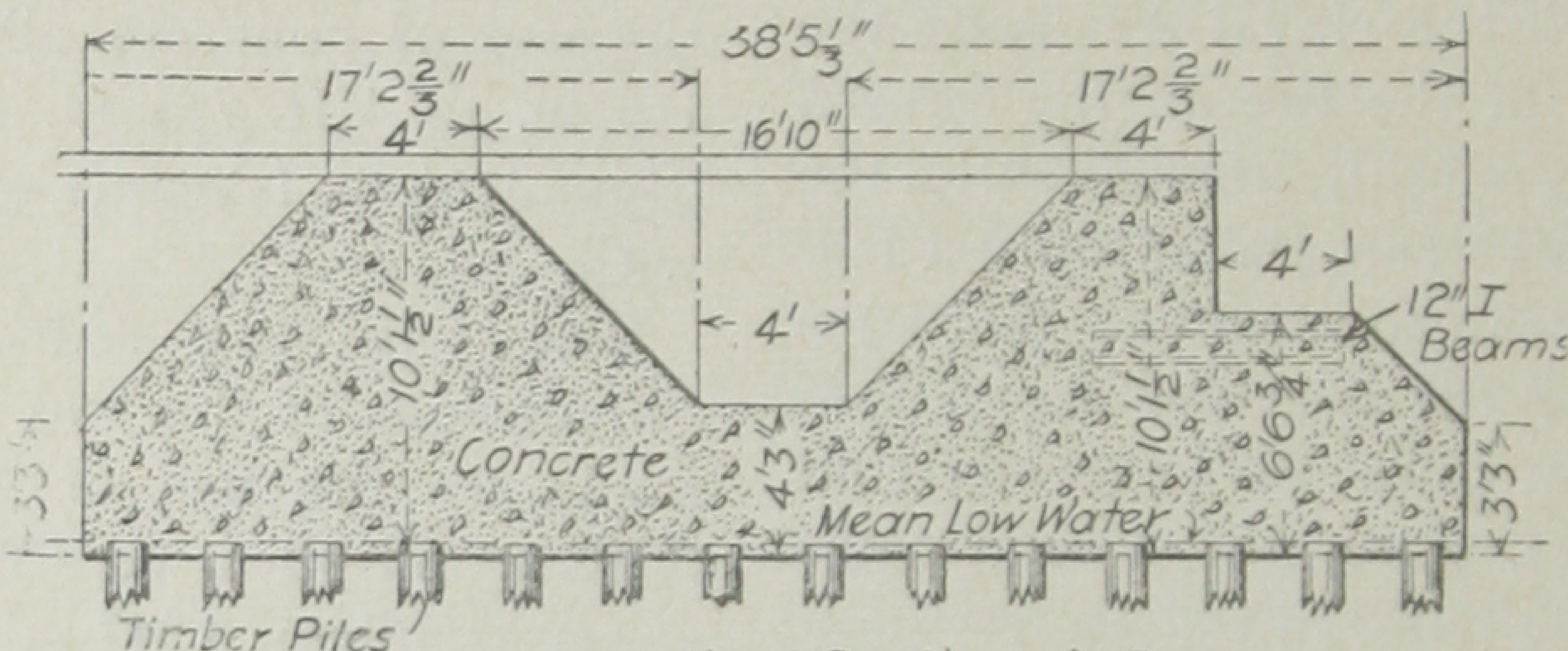
Vertical Section G-H

TABLE 1.—COMPARATIVE COST OF WOOD AND CONCRETE PILES.

	Wood Piles		
2,193 piles	at $9.50	$20,835.50	
4,542 cu. yd. excavat'n.	" .40	1,816.80	
3,250 " concrete	" 8.00	26,000.00	
5,222 lb. I-beams	" .04	208.88	
Shoring and pumping		4,000.00	
Total cost			$52,861.18
	Concrete Piles		
855 piles	at $20.00	$17,100.00	
1,038 cu. yd. excavat n	" .40	415.00	
986 " concrete	" 8.00	7,888.00	
Shoring and pumping			
Total cost			$25,403.00
Difference in cost			$27,458.18

The saving in the cost of foundations by the use of concrete piles was $27,458.18, or more than half of the original cost of the foundations as designed with wood piles.

The estimate of length of wood piles was taken from the length of wood piles driven in the marine engineering building, a structure about 200 ft. from the library site. Wood piles would have been required 40 ft. in length at a cost of 20 cents a foot, and would have been on an average driven 30 ft. below mean low water, which at 5 cents a foot would mean an average cost of $9.50 per pile.



Vertical Section A-B

For the estimate for excavations it was assumed that the entire site was at an elevation of 7 ft. above mean low water, which is an average of the existing conditions.

The longest concrete pile driven was 29.7 ft., but owing to the solid nature of the soil at the southerly end of the library building, where shorter piles were used, the average length was 16 ft., and the cost of the concrete piles was taken at $20 per pile.

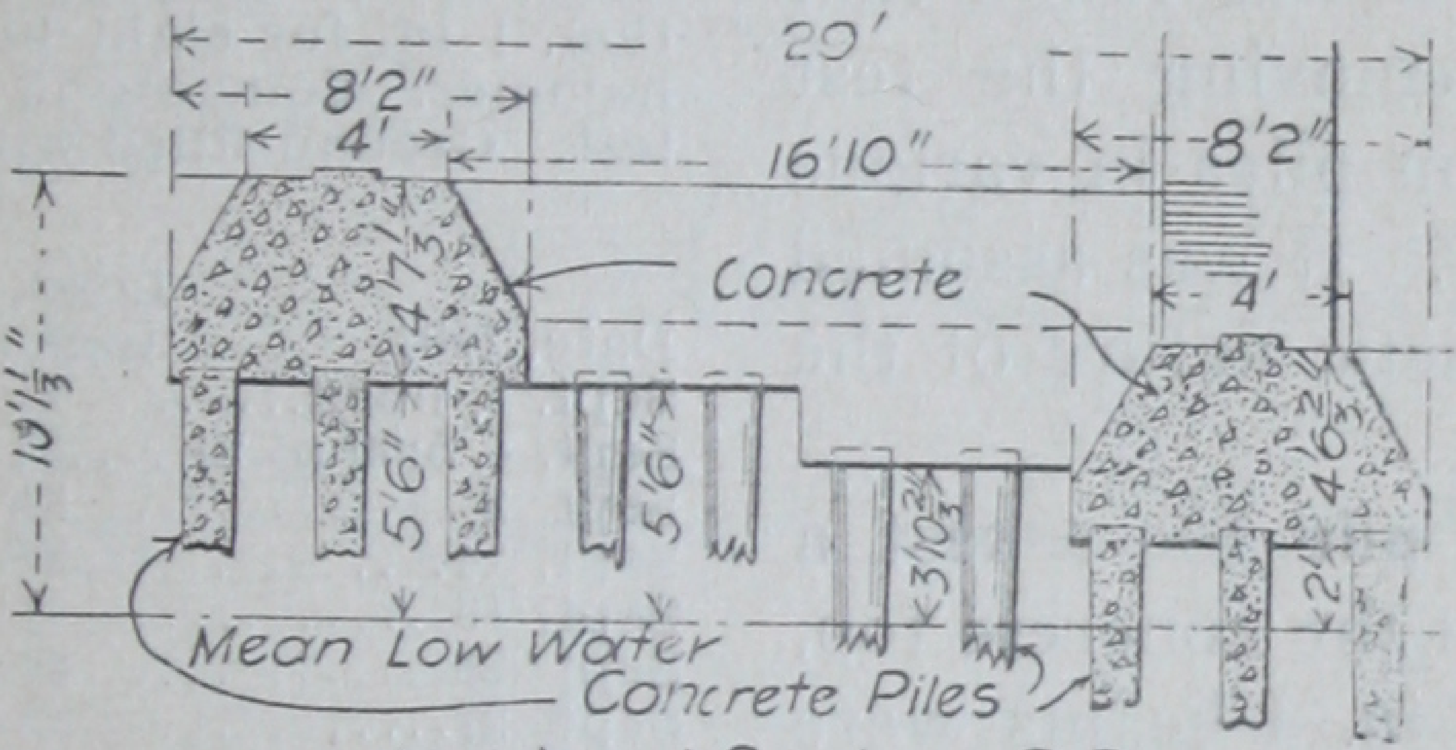
The concrete pile selected was that of the Raymond Concrete Pile Co., of Chicago. It is conical in shape, running from 6 in. in diameter at the bottom to 20 in. at the top. Owing to this conical shape the ground is compacted and a much shorter pile can be used with this style than with a cylindrical pile. The difference in bearing power between a conical and cylindrical pile was shown by an experiment tried on this work at the Naval Academy. A Raymond pile core tapered from 6 in. at the point to 20 in. at the head, was driven 19 ft. until the penetration under two blows from a 2,100-lb. hammer falling 20 ft. was ⅞ in. A wood pile 9½ in. at the point and 11 in. at the head and having the same length, 19 ft., as the conical pile, had a penetration of 5 5-16 in. under two blows of the same hammer, falling 20 ft. This pile was driven after the concrete pile and about 2 ft. from it, thus showing the comparative bearing power between a conical and a cylindrical pile of the same length.

These piles of the Raymond style are driven by the use of a hollow steel core 6 in. in diameter at the point and 20 in. at the head. The cores used on this work were 20 and 30 ft. in length. The exterior pieces of the core are spread and held in place during the driving by a wedge device. The core is held in the leads of the pile driver by steel plates, fastened to its top, which form guides to slide in the leads. The top of the steel core is protected by a hard wood cap-block which sets in a cavity made for it. This block receives the blow of the hammer and has to be renewed from time to time.

The sheet-steel shells are formed on the work in an extra heavy cornice brake machine, and are made in 8 ft. sections with locked seams. The sections are telescoped, the point of the core is raised about 8 ft. and inserted in the smallest section; then the other

sections are drawn up around the core by a line from the hoisting engine on the driver. Two drivers were used on the work at the Naval Academy, one with a 2,240-lb. drop hammer and the other a steam hammer of the Vulcan make, weighing 3,000 lbs. The steam hammer was found more satisfactory, working much more rapidly. This was partly due to the fact that the steam hammer was mounted on a turn-table, and was able to turn in a circle by its own power. It was also provided with an extension top by which the core could be raised, or lowered, if necessary, in a trench below the driver.

The first piles were driven until twenty blows with the steam hammer caused a penetration of 1 in. This was found to be very severe on the steel core, and later tests on loaded piles proved that it was unnecessary to have such a small penetration, and it was reduced to eight blows for a penetration of 1 in.



Vertical Section C-D

When the driver with the drop hammer was brought on the work some comparisons had to be made between the blows of the two hammers, so that the cores would be driven to the same penetration, to give an equal bearing for all parts of the building. A core was driven with the steam hammer until the penetration with eight blows was 1 in. This core was detached from the leads of the steam hammer and left standing in the ground; then the driver with the drop hammer was moved up and four blows from the 2,240-lb. hammer falling 20 ft. was found to drive it 1 in., or a penetration of ¼ in. for a blow. As previously stated, eight blows of the steam hammer in rapid succession drove the core 1 in., and the conclusion was reached that one blow of the drop hammer was equivalent to two blows of the steam hammer.

The tests were made by loading the piles, and it was estimated that all piles with the same penetration as the test piles would have the same bearing power. A 17½-ft. pile driven with a 20-ft. core, 6 in. in diameter at the point and 20 in. at the head, having a penetration of 1 in. under twenty blows of the steam hammer, was loaded with 41 tons. Levels were taken during the loading and at intervals for one month. At the end of the month the total settlement was 0.007 ft. or 3-32 in.

Another 28½-ft. pile driven with a 30-ft. core, 6 in. at the point and 20 in. at the head, had a penetration of 5-16 in. under ten blows with the steam hammer. This pile was loaded with 42 tons. Levels were taken during the loading, showing a settlement of 0.002 ft., and at intervals for one month, showing no additional settlement. This pile was driven outside of the old sea wall in that portion of the land reclaimed from the Severn River, which had been filled with sand and mud three years previously.

A test pile was driven at the northerly end of the building on that part of the ground reclaimed from the Severn River. This pile was driven with a 30-ft. core a distance of 22½ ft., having a penetration of 1 in., for eight blows with the steam hammer. The diameter of the pile was 6 in. at the point and 16 in. at the head. It was loaded with 41 tons and had a settlement of 0.007 ft., or 3-32 in. Ten days

later it showed a total settlement of 0.009 ft. The load was then increased to 45 tons, with no additional settlement, and finally it was increased to 66½ tons, showing a total settlement of 0.035 ft., or less than 7-16 in. There was no additional settlement when the load was removed six days later.

Table No. 2 gives the elevations taken on this pile during the month the test was being made.

It will be noticed that the pile rose about ⅛ in. when the load was removed. This difference was at first supposed to be an error in the level work, but was checked several times, giving the same result. This led to a study of past records on piles of other systems, and it was found that this rising after removing the test load had occurred on piles in various parts of the country. It was assumed to be due to the elastic nature of the soil.

In preparing the pile for a test a spike was grouted in the concrete top, then two double 12-in. I-beams were placed on top of the pile, leaving room enough between them for a level rod to be held on the spike. On the I-beam a platform was made of 12x12-in. beams 12 ft. long, projecting on either side. This platform was loaded with chain, leaving a hole in the center for the level rod. An elevation was taken on the spike before loading, and while the load was being applied, also at intervals for a month. These elevations were taken from a nearby bench mark.

The concrete was a 1:3:7 mixture with Catskill Portland cement, sand and ⅛ to ¾-in. gravel. The average of 78 neat cement Government tests was: Twenty-four hours, 308 lb.; 7 days, 661 lb.; 28 days, 745 lb.

TABLE 2.—TEST ON CONCRETE PILE, ACADEMIC BUILDING, U. S. NAVAL ACADEMY.

Concrete mixture, 1 : 3 : 7. Length of core, 30 ft. Length of pile, 22½ ft. Diameter of pile head, 16 in. Diameter of point, 6 in. Penetration, 1 in. for eight blows No. 2 Vulcan steam hammer. Concrete 13 days old at beginning of test. Ground filled with sand and mud in 1901.

Date, 1904.	Load, tons	Settlement: Since last reading	Settlement: Total
Sept. 1, noon	21	—0.005	0.005 ft = $\frac{1}{16}$-in.
Sept. 1, 5:00 p. m.	31	—0.000	0 005 " = $\frac{1}{16}$-in.
Sept. 3	31	—0.002	0.007 " = $\frac{3}{32}$-in.
Sept. 14	31	—0.000	0.007 " = $\frac{3}{32}$-in.
Sept. 16	41	—0.000	0.007 " = $\frac{3}{32}$-in.
Sept. 26	41	—0.002	0.009 " = $\frac{7}{64}$-in.
Sept. 27	45	—0.000	0.009 " = $\frac{7}{64}$-in.
Sept. 28, 11:30 a. m.	50	—0.004	0.013 " = $\frac{5}{32}$-in.
Sept. 28, 3:30 p. m.	54	—0.004	0.017 " = $\frac{7}{32}$-in.
Sept. 29	61	—0.004	0.021 " = ¼-in.
Oct. 1	66½	—0.010	0.031 " = ⅜-in.
Oct. 4	66½	—0.004	0.035 " = $\frac{7}{16}$-in.
Oct. 10	66½	—0.000	0.035 " = $\frac{7}{16}$-in.
Oct. 26	0	+0.009	0.026 " = $\frac{5}{16}$-in.

DEPARTMENT OF THE NAVY
BUREAU OF YARDS & DOCKS

WASHINGTON, D C

July 8, 1905

Raymond Concrete Pile Co.
Chicago, Ills.

Dear Sirs:

While stationed at the Naval Academy in connection with the work of improvement, I supervised with much interest the placing of your concrete piles in the foundations of the Academic Group of

buildings.

The general description of this work as given by Mr. Walter G. Harper, C.E. in the Engineering Record, coincides with my observations.

Yours truly

A. C. Cunningham
Civil Engineer
U.S. Navy.